

MANAGING AN R&D CONTRACT WITH THE GOVERNMENT

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Formal project-management procedures, required for U.S. Government contract execution, provide a basis for management of R&D-intensive projects within AT&T. A \$19.7-million R&D contract, awarded by the Defense Advanced Research Projects Agency (DARPA), provided an opportunity for the gallium arsenide (GaAs), integrated-circuit (IC) project team to develop basic project-management procedures that extend well beyond the realm of government-contract management. For example, the project-management approach developed for execution of the DARPA contract is directly applicable to the product-realization process, to emerging quality and productivity initiatives, and to fiscal accountability in AT&T's strategic business units (SBUs). Baseline planning becomes the cornerstone for critical SBU projects, and formal milestone tracking and control ensure high-level visibility of project progress. Product-development teams become customer champions for specific deliverables, and the core strength of a project-management department emphasizes a business-like approach to the R&D challenges of the 1990s.

Introduction

"Do it right the first time!" This universal goal of the manufacturing industry applies to project management as well. We all want to do it right the first time. That is, we want to start with well-defined customer needs and requirements, formulate the right plan, and execute the defined tasks, so that "product" is delivered on time—exactly as the customer requested. A contract offering by the Defense Advanced Research Projects Agency of the U.S. Department of Defense (DoD) gave an embryonic, gallium arsenide, integrated-circuits development and manufacturing organization the chance to do it right the first time.

In this paper, we provide a case study of the four-year DARPA contract awarded to AT&T Bell Laboratories in March 1987. We focus on our experience with the project-management tools needed to allow the right things to happen at the right time. Most important, we describe how these tools apply, under the widely differing circumstances in AT&T's business units, to the development and manufacture of high-performance photonic and electronic components. These management tools:

- Helped define customer needs and requirements.
- Fostered good communications among teams of development and manufacturing engineers.
- Increased the likelihood of product delivery that conformed to customer expectations.

Contract execution exemplified the basic challenges of the product-realization process, and quality management and improvement were essential to meet the government's stated objectives of productivity and control. All this presented a special challenge because no one in the responsible AT&T organization had prior experience with government-contract work. Thus, all phases of the project had to be learned and performed for the first time.

In the rapid-fire developments of the 1990s, we don't often get a second chance to do it right. So, from this perspective, the experiences we describe here should be interesting to other groups in AT&T facing similar challenges. (Panel 1 defines acronyms and terms used in this paper.)

Background

In this section, we describe the events that led to the DARPA contract award to AT&T Bell Laboratories in Reading, Pennsylvania. Because the contract was a major force in the evolution of AT&T's GaAs IC technology, we review the highlights of this technology development and show how the contract award became a pivotal event. Two prior contract awards in DARPA's program formed a sequence of milestones leading to the award of this contract.

GaAs IC Technology at AT&T. Development and exploitation of GaAs IC technology are part of a comprehensive technology-development effort at AT&T that derives its importance from the singular properties of compound semiconductors. In contrast to elemental semiconductors such as silicon and germanium, compound semiconductor-materials offer systems designers exciting and special opportunities for high-speed electronics and photonics.¹

Designers may select an alloy composition from a variety of chemical group III and group V elements to meet certain performance criteria.² (Groups III and V refer to classifications of materials in the Periodic Table of Elements.) Well-known examples include the use of various alloys of aluminum, arsenic, gallium, indium, and phosphorus to produce lightwave sources and detectors for high-bit-rate lightwave-communications systems. Likewise, high-speed electronics may be provided using GaAs and its alloy with aluminum (AlGaAs).³

In the late 1970s, AT&T developed the technology for GaAs-based electronics and transferred this technology to manufacture. The next decade was marked with AT&T's successful introduction of a 1.7-Gb/s (gigabits per second) lightwave-communications system that, for the first time, used GaAs ICs manufactured at the Reading facility. Predictions of rapid growth in the industry prompted AT&T to combine its GaAs R&D and manufacturing effort as an independent business unit in Reading where a modern, 10,000-square-foot clean room was built to meet the most demanding processing technologies. The newly formed organization also introduced molecular-beam epitaxy (MBE) as a production system. (MBE is an atomically exact, layer-deposition system for creating circuit structures.⁴) Thus, the stage was set for AT&T's initiation as a DARPA contractor.

DARPA's Pilot-Line Program. DARPA is interested in gallium arsenide for military applications because of the higher performance and greater resistance to ionizing radiation achieved with this material.⁵ DARPA's program plan includes funding for three pilot lines, under separate

Panel 1. Abbreviations, Symbols, and Terms

AlGaAs — aluminum gallium arsenide	matrix management — a concept where organizations of functional specialists temporarily assign people to support specific projects
ACWP — actual cost of work performed	MBE — molecular-beam epitaxy
ARPANET — Advanced Research Projects Agency Network	MESFET — metal semiconductor field-effect transistor
BCWP — budgeted cost of work performed	NOSC — Naval Oceans Systems Command
BCWS — budgeted cost of work scheduled	product-realization process — the process of bringing a product into existence, from inception through deployment to customers
CAD — computer-aided design	RFP — request for proposal
CV — cost variance	SARGIC — self-aligned, refractory gate, integrated circuit
D-FET — depletion field-effect transistor	SBU — AT&T strategic business unit
DARPA — Defense Advanced Research Projects Agency	SDHT — selectively-doped heterostructure transistor
DARPA/DSO — Defense Sciences Office of the Defense Advanced Research Projects Agency	SEU — single-event upset
DoD — U.S. Department of Defense	SOW — statement of work
DX — unknown defect	SQT — single quantum-well transistor
E-FET — enhancement field-effect transistor	SRAM — static random-access memory
FMA — failure-mode analysis	SV — schedule variance
GaAs — gallium arsenide	TABS — tracking and budgeting system
HFET — heterostructure field-effect transistor	VLSI — very-large-scale integration
IC — integrated circuit	WBS — work-breakdown structure
JFET — junction field-effect transistor	
LSI — large-scale integration	

contracts, to DoD contractors who use gallium arsenide circuits in their most advanced designs (see Table I). The three DARPA contracts supported and encouraged the development of manufacturing capability for high-performance GaAs ICs to meet the needs of future military systems. The contracts emphasized resistance to radiation effects as a goal for technology development, and all the contractors were instructed to use the advantages of GaAs materials to produce high-speed circuitry that operates at low power.

The first of the pilot-line contracts was awarded in May 1983 to Rockwell International (Newbury Park, California) and Honeywell (Minneapolis, Minnesota), who executed the contract as a team. In November 1984,

the second contract was awarded to McDonnell-Douglas (Huntington Beach, California).

The third pilot-line contract—awarded to the AT&T team—was created to:

- Prove manufacturing capability for digital, GaAs integrated circuits in a pilot line set up by the contractor.
- Show high-speed, low-power, radiation-tolerant performance of an advanced GaAs IC technology.
- Design and build working circuits with 3,500 to 5,000 gates.
- Provide user-friendly design tools for customers of the pilot line.

Clearly, the common interests of DARPA and AT&T stimulated our enthusiastic response in early 1986

Table I. DARPA's Pilot Line Contracts for GaAs IC Manufacture

Item	Pilot Line I May 1983	Pilot Line II November 1984	Pilot Line III April 1987
Contractor (subcontractor)	Rockwell International Honeywell	McDonnell-Douglas	AT&T (Hughes Aircraft McDonnell-Douglas)
Theme	Low power, radiation hardness, GaAs LSI line	GaAs pilot line for space-borne memory chips	GaAs pilot line for high-performance components
Technology	MESFET depletion mode	JFET optimized memory	SARGIC/HFET custom logic
Demonstration vehicle	16-kb SRAM, 10-ns access, 1 μ W/bit	16-kb SRAM, as before	4-kb SRAM, 5-ns access
	6k gate array for logic	—	Logic circuits 200 MHz
	—	—	User-friendly CAD
Radiation hardness test	$> 10^7$ rd total dose	$> 10^{11}$ rd/s transient dose SEU immunity	$> 10^8$ rd total dose $> 10^{10}$ rd/s transient dose SEU immunity
Foundry	Pilot line for 3-inch wafers at 100-per-week yield to enable VLSI-circuit complexity		

NOTE: For the gate array, k = 1,000; for the SRAM, kb = 1024 bits. MHz = megahertz, μ W/bit = microwatt per bit, ns = nanosecond, rd = rad, rd/s = rads per second.

to the U.S. Government's request for proposal (RFP). The only problem was that AT&T was "unknown" as a major contractor for electronics components, and no one in the GaAs business unit knew how to go about the business of responding to a RFP.

The pilot-line contract, as eventually proposed by the AT&T team, contained numerous technical challenges. AT&T offered a complex technology requiring extremely precise layer-growth control and robust wafer processing. With this technology, both enhancement and depletion type field-effect transistors (i.e., E-FETs and D-FETs) would be produced simultaneously on the integrated circuit. At the start of the contract, the existing device models were inadequate for circuit design, and the manufacturing techniques required to achieve large-scale integration (LSI) had not been tested or validated.

Many "firsts" would occur during the execution of this contract:

- For the first time, MBE heterostructure, layer-growth technology would be used in the manufacturing environment. (A *heterostructure* is a multilayer structure of dissimilar alloy compositions.)
- LSI GaAs digital circuits that exceed contract speed and performance specifications would be manufactured.
- Laser repair for GaAs memory circuits would be developed.
- High-speed testing [up to 400 MHz (megahertz)] would be done.
- The first computer-simulated models of the GaAs IC technology would be realized.

AT&T's successful bid had a contract value of

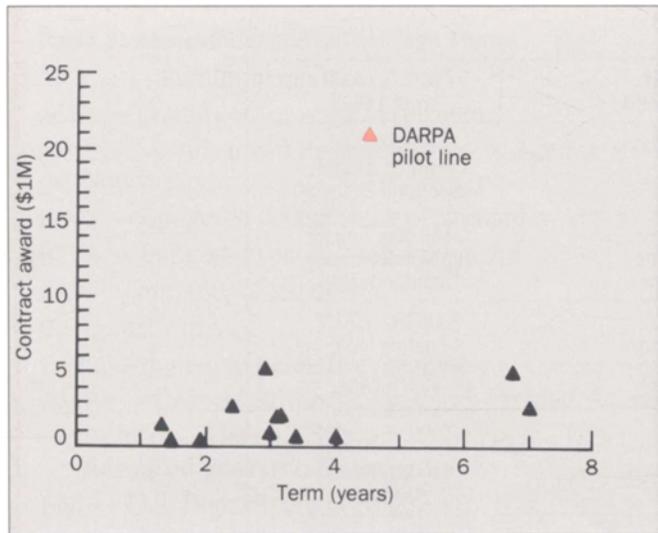


Figure 1. The Electronics Technology Area of AT&T Bell Laboratories benefits from government support of many contracts valued at less than \$10 million each. So, the DARPA pilot-line contract, the only one awarded at more than \$20 million with fees, is exceptional because of the management challenges it offers. The data shown were accumulated in December 1990.

\$19.7 million (with fees) for a term of four years. As Figure 1 shows, this contract became the most-significant project of its kind in the Electronics Technology Area of AT&T Bell Laboratories.

In addition to the government award, AT&T committed to share resources valued at \$17 million to bring the contract-funding total to more than \$36 million. Nearly 50 engineers would be funded, in part, during the peak contract activity. The sponsoring organizations included:

- Eight AT&T Bell Laboratories departments representing three divisions in the Electronics Technology Area. (These organizations are located at Murray Hill, New Jersey, and at the Cedar Crest facility in

Allentown, Pennsylvania.)

- Two engineering departments in AT&T Microelectronics (Reading, Pennsylvania).
- Two R&D groups at Hughes Aircraft (El Segundo and Torrance, California), a subcontractor to AT&T.
- One R&D group at McDonnell-Douglas (Huntington Beach, California), the other AT&T subcontractor.
- Contract-administration support groups at AT&T Bell Laboratories (Whippany, New Jersey) and at AT&T Federal Systems' Advanced Technology Division (Guilford Center, North Carolina).

Figure 2 shows the widespread participation in this contract, including the contracting agency and relevant associate contractors representing the U.S. Government. The dispersion of these working groups presented some interesting problems in communications and management.

DARPA Pilot Line III, A Case Study

In this section, we define the five parts of the life cycle of a typical R&D contract with the U.S. Government: approach, definition, planning, execution, and delivery. The DARPA pilot-line contract serves as a model for each phase.

We also describe the challenges (both management and technical), the management tools used, and most important, how our experiences with the DARPA contract affected other projects in the high-performance IC business unit in AT&T Microelectronics.

Management Approach. During the first phase of the project, a management structure was established within the GaAs IC organization in Reading for project oversight and control. Even before AT&T had bid on the DARPA contract, the director of the GaAs integrated-circuits laboratory elected to dedicate about 5 percent of his technical resources to project management. The new project-management group had no direct technical development or manufacturing responsibilities, but it was empowered to manage specific projects across functional organization lines. The existence of this group was

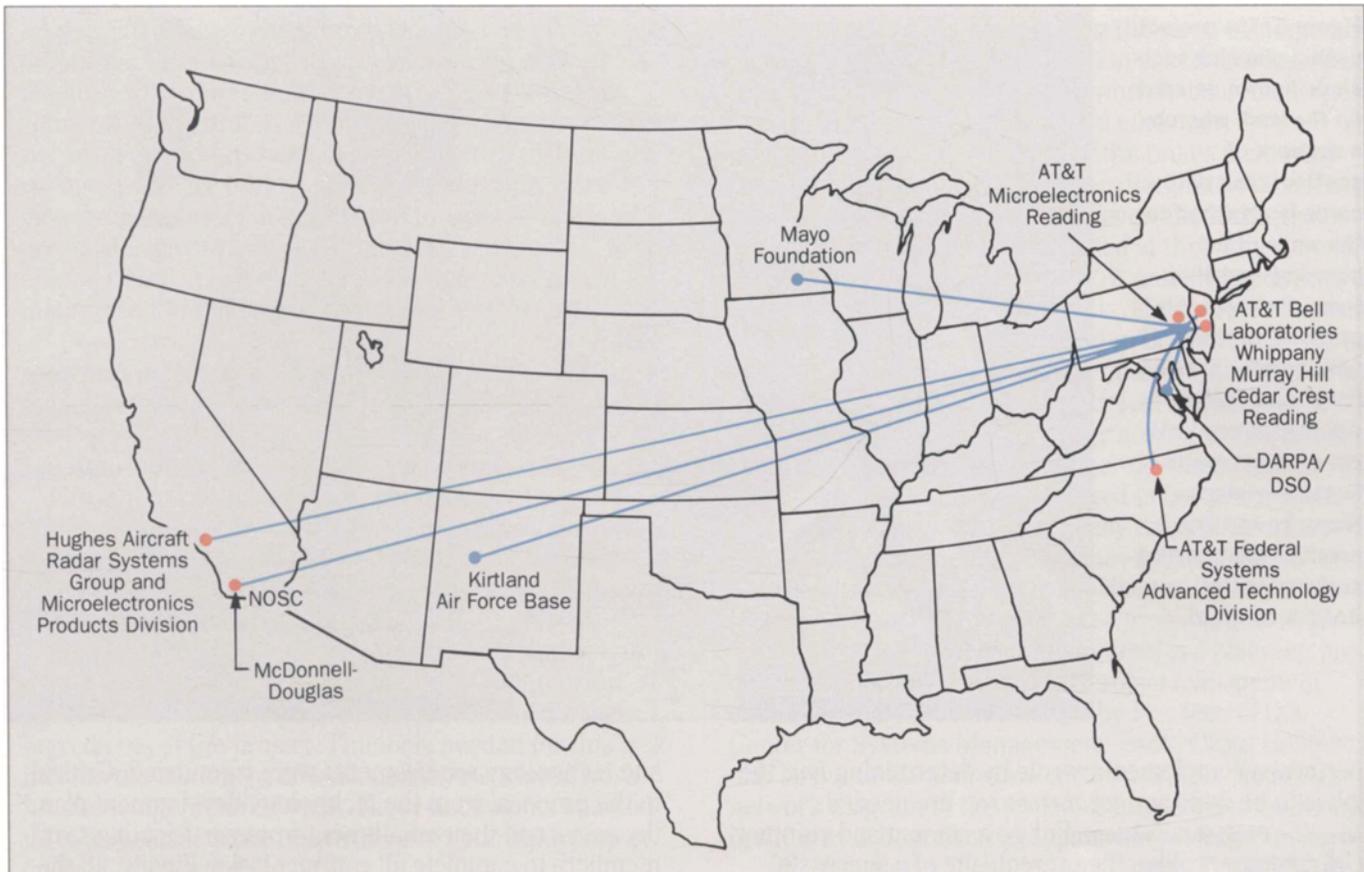
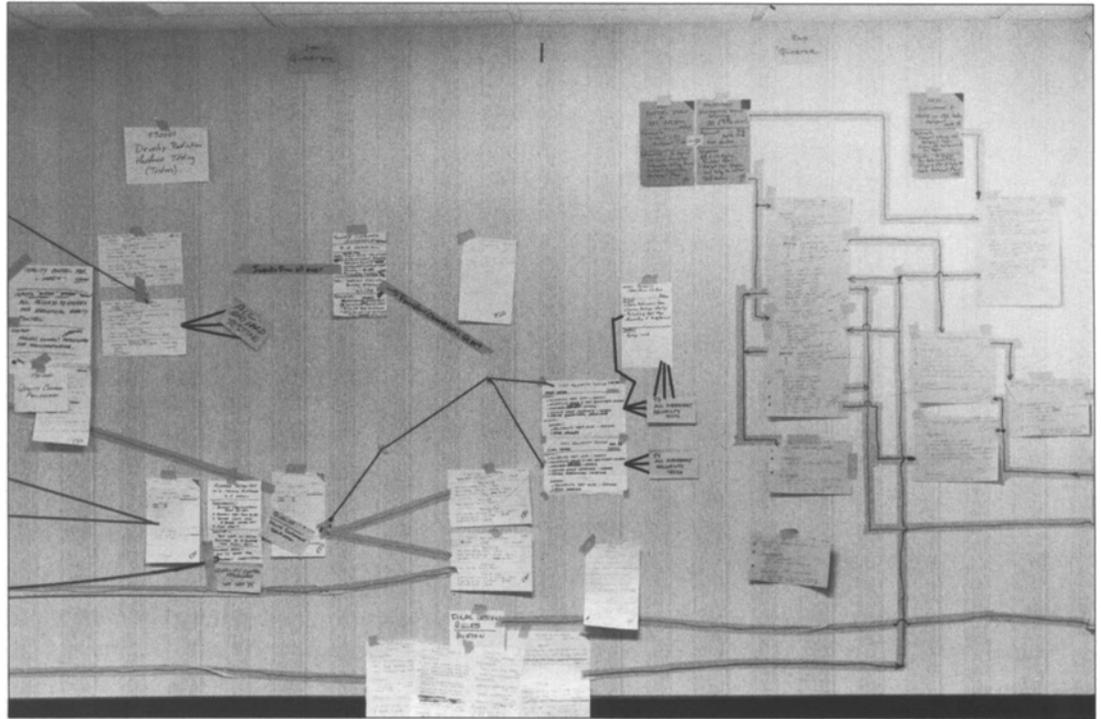


Figure 2. Groups at AT&T, Hughes Aircraft, and McDonnell-Douglas were responsible for contract execution. In addition, the AT&T project manager had to provide communications links to associate contractors at the Mayo Foundation in Rochester, Minnesota, and the Naval Oceans Systems Command (NOSC) at San Diego, California; and to the contracting agencies at Kirtland Air Force Base in Albuquerque, New Mexico, and DARPA/DSO in Arlington, Virginia. Telephone conferences involving key participants were used to maintain control of the contract schedule.

essential to form the core management team for the intricate DARPA contract that was to follow.

The management concept developed for the government contract became useful in other ways. Individuals trained to serve as project managers become made-to-order leaders for numerous projects, where matrix-management principles⁶ are effective. As project managers, these people serve as the single point of contact with their customers on technical matters. They focus on customer needs by deciding *what* has to be done and *when* it's to be done. Functional supervisors

Figure 3. The project used a planning technique known as *cards on the wall*, whereby a network of contract-task data cards is attached to the walls of the planning-workshop room. Because this provided contract-task details, missing links were quickly discovered and critical contract tasks became evident. Here, we see the result of the planning activity for the DARPA contract.



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perform a complementary role by determining *how* the job is to be done and *what resources* are needed.

Project Definition. For government and commercial customers alike, the prerequisite of a successful interaction is a clear statement of the customer's needs and requirements. Normally, this statement is provided in the wording of the contract announcement (i.e., in the broad agency announcement or RFP). For the DARPA pilot-line contract (Pilot Line III), the statement of work (SOW) in the RFP was precise. It described R&D activities, packaged-circuit specifications, test requirements, a schedule for delivery, cost and schedule reporting methods, and the required interactions with other government contractors.

During the proposal-team meetings at AT&T, the details of team organization, management approach,

and technology requirements were formulated. Critical to the proposal were the technology-development plan, the costs, and the commitment from participating team members to complete all contract tasks. Finally, all the good things produced in the proposal-team meetings had to be put in an acceptable proposal format. For this, we employed a specialist consultant, Shipley Associates of Bountiful, Utah. Obviously, this bid and proposal strategy worked. It was especially gratifying to be told by several government reviewers that the AT&T proposal was "the best proposal they ever read."

In reality, the secret to writing a winning proposal was no more than the secret to achieving customer satisfaction by meeting all expectations about the *deliverable*; i.e., the proposal itself. We deduced from the RFP what the customer expected to find in the proposal, and

we predicted how the customer would score competing proposals. Besides offering a believable approach for meeting *all* requirements of the project, we emphasized elements of the proposal that matched evaluation criteria (we even provided a handy cross-reference matrix), and we made sure we offered an uncommon approach that gave proposal evaluators a reason to differentiate our proposal from the others. We also made sure that the proposal was sensibly presented with respect to text formatting and graphics, and that it was easy to read.

To translate the lessons learned from writing a government-contract proposal into ways that AT&T managers should apply the process, we focus here on the key issue: understanding exactly what the customer wants; i.e., the definition of contract terms.

On previous projects, we treated our internal AT&T customers casually, and we allowed undefined requirements to “float” until we could agree (usually under considerable pressure) on what was needed to do the job.

The formalism of government contracting taught us to concentrate on the customer specifications for deliverables and the schedule for delivery as the main ingredients of the project. The tools needed for this task include the statement of work and its associated work-breakdown structure (WBS). These documents enabled us to assign adequate resources and determine project costs at the start of the project.

For example, we asked our internal, lightwave-components customer in AT&T Network Systems for a statement of work that described the circuits, their specifications, and the delivery dates of work proposed for a high-data-bit-rate application. This customer thought the concept was novel and—at times—a waste of time. But the customer cooperated, allowing us to help generate the SOW document that was approved by the responsible department heads on both sides of the contract. The effort was rewarded when the first deliverable date arrived with on-time delivery of GaAs IC products to this important customer.

In later projects involving the same customer, a senior manager in that organization asked that a similar approach be taken to define the work to be done. Repeat business is the mark of a satisfied customer.

Project Planning. Most of the DARPA task managers were uncomfortable with the discipline of the formal planning process used for U.S. Government contracts. Each project task had to be defined at the highest level, using information found in the SOW and other contract documents; and at the “working level,” resource commitments and milestone choices had to be consistent with the WBS and the master implementation schedule for the entire project. Each task manager had to understand the technical capabilities of his or her area of responsibility and had to work closely with other task managers to meet project schedules established in the overall plan.

This approach is especially difficult for R&D projects because invention is often needed to complete the tasks, and contingency plans, or risk-management strategies, must be used to increase the probability of success.

The approach we recommend is a planning procedure commonly described in project-management courses (e.g., the course taught by H. Mooz of the Center for Systems Management, Santa Clara, California) as the *cards-on-the-wall* method. In this method, a network diagram of the project is formed; and each task in the WBS is described by inputs, outputs, and resource requirements on a 5-inch by 7-inch card. The cards are taped to a wall and interconnected with heavy yarn to show their interrelationships. The network chart may then be transcribed to project-management software to create the resource plan needed to complete the contract on schedule, and the formal cost estimate can be made from the plan.

By working together, the task managers from AT&T and Hughes Aircraft formed the complete network for the DARPA contract on the four walls of a motel dining room in three days. Figure 3 shows the result of this activity.

The most important benefit of this planning

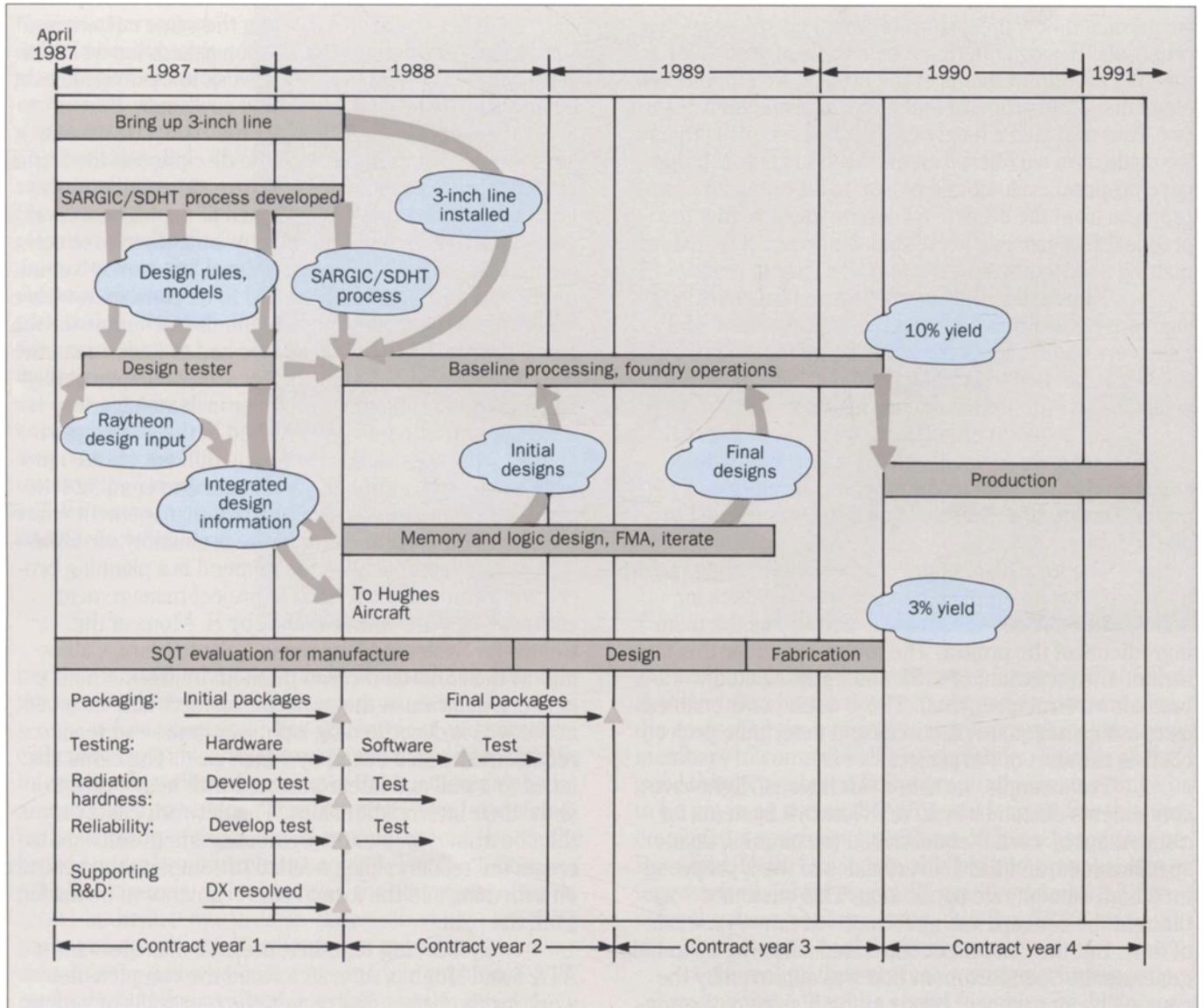


Figure 4. Milestones shown in “clouds” on the Gantt chart represent exceptional challenges to the project. These high-risk events, known as “miracles,” were focal points for the customer and the performing team during execution of the contract. Only three of the miracles failed to happen, but successful completion of the contract was ensured by alternative plans.

activity is the resolution of potential *I forgots*; e.g., the missing project steps or deliverables that provide continuity from one task to the next. Sometimes, important technical issues have to be addressed, and the beauty of the process is that all the people who have inputs are at the same place at the same time. No one has to be called in to provide a solution.

We used this planning process for the DARPA contract, and the method is useful for commercial work as well. Because off-site meetings discourage interruptions and absenteeism, they were essential in the business unit for organizing and planning technology development, introducing quality-improvement methods, and setting up internal-project commitments. However stressful this planning process may be, the work performed has long-term benefits because the entire project is reviewed by all those responsible for its execution.

Project Execution. When the DARPA contract started, we were on our own because we, as fledging project managers, suddenly became the specialist consultants. We were guided by well-known principles:

- Be honest with the customer.
- Communicate within the team.
- Deliver the product on time.
- Control costs.
- Stand back and let good things happen.

Success depended on our ability to do these things, manage change, and contain risk.

The DARPA contract wasn't something we could manage “by the book.” During the off-site planning session, we found several key points in the project schedule where “miracles,” or high-risk accomplishments, had to

happen. To heighten awareness of any pending crisis, we created a Gantt chart (Figure 4) that showed where these miracles were required. We made no pretense about our ability to solve these critical problems, and shared our concerns with the customer. This strategy was beneficial in two ways:

- It neutralized any perception of AT&T arrogance by the customer.
- It eliminated surprise as an element in the execution of this contract.

By allowing the customer to be a participant in our problem-solving efforts, we received help, at the customer's direction, from DARPA contractors who were not involved in the Pilot Line III contract.

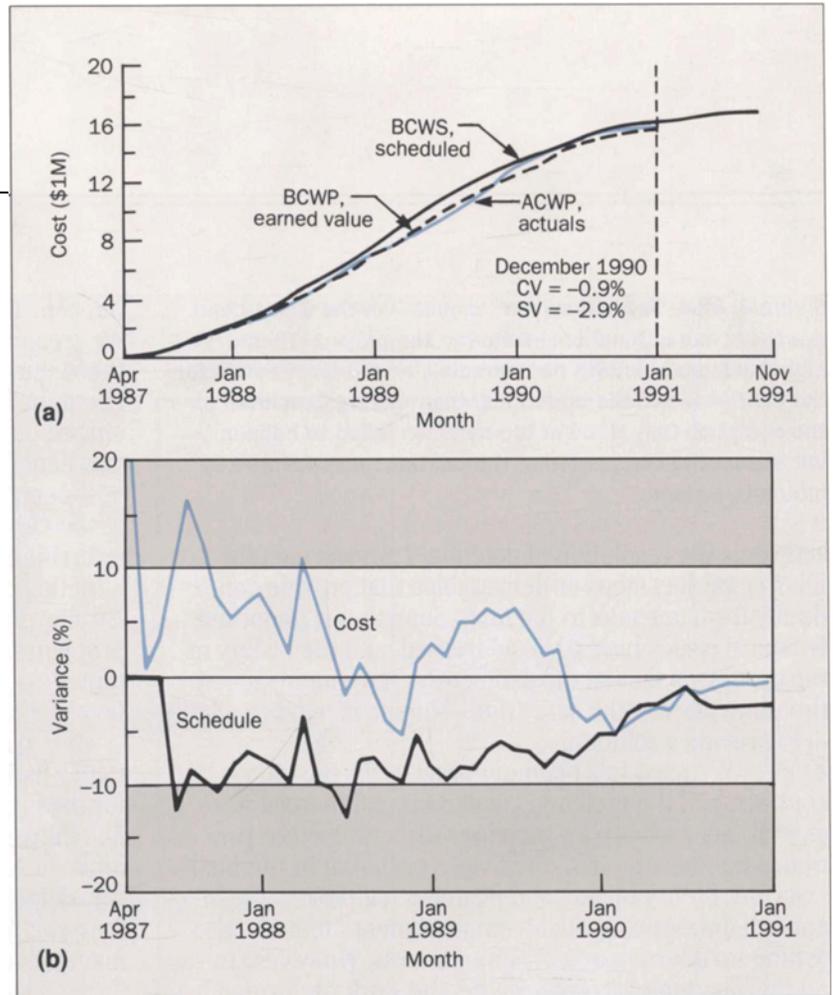
Communications with the customer. Although the customer had scheduled quarterly, on-site reviews to monitor the project, we established a direct communications link between the AT&T project manager and the DARPA office in Arlington, Virginia, so that information could be transferred rapidly. This informal communications link took two forms: electronic mail via ARPANET, and ad hoc meetings at the customer's premises.

During the first three years of this contract, more than 600 electronic-mail messages were exchanged. Also, we made the 300-mile, round-trip drive to Arlington (3 hours each way) for a 1-hour meeting in the customer's office, as required. To date, about ten trips have been made and, in each case, issues that could not be resolved by telephone or electronic mail were resolved in person.

We made every attempt to provide whatever the customer needed because, as Marshall Field (a Chicago, Illinois, retailer) said many years ago,⁷ “Right or wrong, the customer is always right.”

Communications within the team. The need for communications within the team was equally important. With diverse groups scattered across the country, we elected to conduct a weekly teleconference with 6 to 8 locations represented by a total of 30 to 40 people. Each week, the agenda for the upcoming teleconference was published

Figure 5. Performance metrics for the DARPA Pilot Line III contract. (a) Contract cost and schedule performance. The curves represent budgeted cost of work scheduled (BCWS), budgeted cost of work performed (BCWP), and actual cost of work performed (ACWP). By assigning dollar values to contract milestones (i.e., earned values), we can plot the data on the same scale. At the end of fiscal December 1990, the cost variance (CV) was -0.9% , and the schedule variance (SV) was -2.9% . (b) Variation of project cost and schedule data compared with ACWP and BCWS, respectively. A positive percentage denotes favorable results; a negative percentage means unfavorable results. Points that fell within the shaded areas had to be explained to the contracting agency when they occurred. Quarterly updates enabled project managers to adjust the contract focus so that both CV and SV were eventually controlled to within $\pm 5\%$. The contract is expected to be completed on schedule with no significant cost over- or underrun.



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with the minutes of the previous meeting.

During the teleconference meetings, which lasted no longer than one hour, only project results and coordination issues were discussed. Long, tangential discussions were discouraged; if needed, smaller groups of key personnel were assigned to address critical problems in separate meetings. Because all tasks in the WBS were represented, connections to all the appropriate people could be made during the teleconference.

Inevitably, change occurs. It may result from unforeseen technical difficulties or from changing business conditions in the contract environment. For the DARPA contract, we lost systems-design leadership because another contractor fared poorly and was ordered by DARPA to stop work. This contractor was responsible for providing us with specifications for

circuits we were required to build. To meet contract objectives, we had to seek input from other DoD contractors to identify suitable substitutes.

As another example, we formed ad hoc teams of key engineers from various tasks who were assigned to work on particularly thorny issues. This proved to be an effective way to make progress when the going was rough. Today, the concept is used effectively across the GaAs business unit.

For the DARPA project, we instituted rigorous change control by formally defining the circuit specifications and performance, and by documenting all the process steps (using corporate standards). Technology enhancements were introduced in a controlled and documented environment.

Under the conditions of matrix management,

the project manager must exercise leadership without authority; thus, full cooperation of the technical organization is required to keep the effort at its planned level. For the DARPA contract, we used a time-card tracking and budget system (TABS) that tabulated time charges for every individual assigned to the project. (The TABS software is provided and maintained by the Government Program Planning Center at AT&T Bell Laboratories in Whippany, New Jersey.) With TABS, the time charges on each Friday's time cards were available to us by the end of the following Tuesday, two weeks before the "official" release of time-card data. Thus, without much additional effort, we could detect personnel changes in time to prevent project delays.

During a four-year contract, few organizations have absolute stability in personnel assignments; we are no exception. Several task managers changed positions, and certain key personnel were reassigned or left the organization. These changes were addressed promptly, even if it meant doing the job ourselves. This is the advantage of a resident project-management organization whose members have a solid technical background.

Because matrix-managed projects depend so much on the project manager's ability to secure the loyalty and dedication of the team, it's important for corporate managers to help as much as possible by clearly "anointing" the project manager as the person in charge, the person who is the single point of contact with the customer. The project manager represents the customer to the functional organization; and, if the goal is to do the right thing for the customer, the project manager should have no trouble marshaling support for the task at hand.

Cost and schedule tracking. Most government contracts require disciplined cost and schedule tracking, and the same techniques can be used for commercial projects. Every three months, DARPA-contract task managers provided a six-month plan of activities, and they assigned a dollar value (i.e., earned value) to the declared short-term milestones. AT&T-developed software (i.e., a cost and schedule display system) was used to prepare a

monthly administrative summary for the DARPA contract based on reported milestone completions. (The cost and schedule software is also provided and maintained by the Government Program Planning Center.) Key metrics were calculated and monitored:

- Actual cost of work performed (ACWP)
- Budgeted cost of work performed (BCWP)
- Budgeted cost of work scheduled (BCWS).

Two metrics—cost variance (CV) and schedule variance (SV)—that show variance from the targets were derived from the above data:

$$CV = BCWP - ACWP$$
$$SV = BCWP - BCWS$$

Figures 5a and 5b show standardized plots of all the metrics just described. It is a testimony to the performance of the DARPA contract team that both cost and schedule were kept under control.

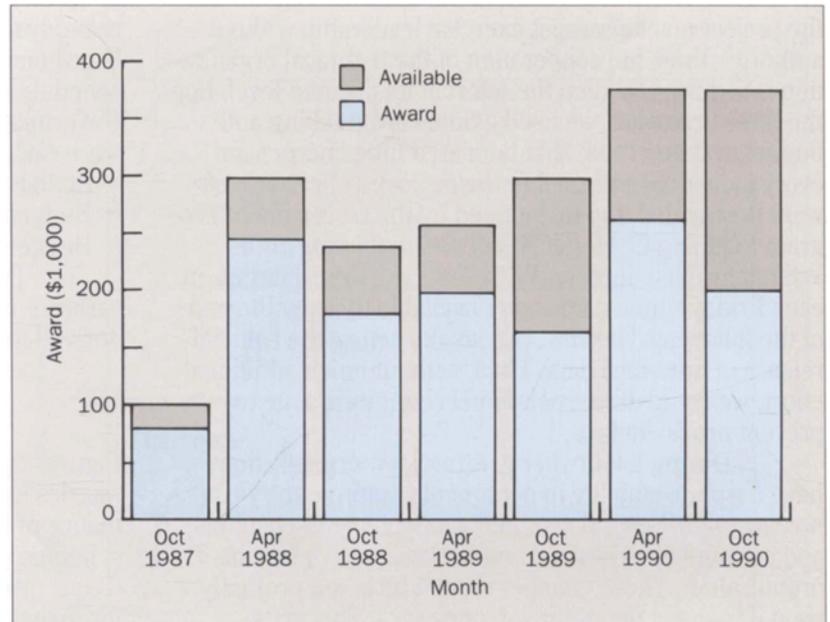
Periodic reviews. The most important instrument for managing a complex project is the technical review process. DARPA required a quarterly review of contract status before a review team of technical experts representing a variety of government agencies and selected independent contractors.

The formal review, a painful process, encourages the performing organization to assess critically the accomplishments and problems that arise during contract execution. To provide the highest level of expertise on each topic reviewed, nonsupervisory personnel made short presentations directly to the DARPA review team without management interference. Each of the formal reviews lasted two full days.

Remarkably, the reviews became an important communication tool for the whole organization. Live telecasts were made to a remote location so that people not associated with the contract could stop in for a quick update in a particular area of interest without interrupting the review meeting.

Following the conclusion of each contract-status review, the customer's project manager solicited critical

Figure 6. Monetary incentive for desired contract performance was provided by the award fee as determined by a government evaluation team. Generally, the award exceeded 85% of the available fee, and evaluators noted the strong technical performance and excellent contract management when awarding these high scores.



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feedback from the Government review team in a closed-door caucus. The feedback was summarized and communicated directly to the AT&T project manager, who issued a written report to the team and to relevant AT&T managers. Thus, important issues raised were subject to immediate action by the team members, and progress on these issues would be reported at the following review.

Delivery and Rewards. The DARPA contract has modest product-delivery requirements. The essence of the project is the demonstration of a technology for manufacturing high-performance components with a large scale of integration. The technical reach is significant. Even though higher levels of performance have been achieved, none of the circuits produced thus far meets the full military specifications. Nevertheless, customer satisfaction with project management and execution has been reasonably high.

Because this is a *cost plus award fee* contract, the contracting agency, DARPA, can attach a monetary value

to contract performance. Up to 10 percent of the contract value is available for distribution, and the award distribution is calculated according to a point-scoring system determined by a DARPA-appointed, award-fee review board. The scoring system is based on a maximum score of 100 percent, and the award is proportional to the amount that the point score exceeds 50 percent. Figure 6 shows the history of award-fee distributions for the DARPA Pilot Line III contract.

The award-fee concept does not necessarily apply directly to commercial projects; however, it is important to recognize that some barometer of customer satisfaction is a critical part of any project undertaking. Also, it is important that the project manager recognize how the project customer and the corporate customer (i.e., company management) relate to the project. Both customers may have differing requirements and metrics for successful performance. The project manager has to do a balancing act to ensure their happiness as the

project unfolds.

For example, a pronounced drop in the award fee in October 1989 reflects the award-fee board's disappointment in our ability to address major technical issues that measurably slowed progress. A change of priorities within the AT&T business unit created a shortfall in the resources available to resolve the technical problems. Thus, significant stress was created when the "other" customer, AT&T management, came up with a view of project priorities that differed from DARPA's, the contract customer. Our immediate response was a quick trip to Arlington to review opportunities to reconcile these differences. Together, we found a solution. Six months later, some customer confidence was restored when we reported significant progress in the redirected project.

We cannot underestimate the importance of the conflict between corporate (AT&T) and customer (DARPA) interests. Here, we were participating in a DARPA program spanning more than a decade of contract activities at a cost to the U.S. Government of about \$130 million. When the contract was awarded to AT&T, the AT&T program in gallium arsenide was in its infancy, and a long-term corporate plan had not yet been defined. As the AT&T objectives became better understood, it became clear that the corporate and government views of future business opportunities in gallium arsenide were diverging.

The lesson learned here is: Any contract with long-term influence must be totally consistent with the company's plans and commitments if mutually compatible interests are expected to prevail throughout and beyond the contract's life cycle. Without this compatibility, it is not advisable to seek contract support only for short-term gain.

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Specific recommendations to commercial-sector project and team managers can be made. For example, emerging new-business directions emphasize quality and productivity initiatives, product-realization programs, and

fiscal accountability. Common to all these are certain fundamentals of a project-management discipline we have described here. If a definitive work statement exists, then baseline planning becomes the cornerstone for critical projects, and formal milestone tracking and control ensure high-level visibility for project progress.

Product-development teams are customer champions for specific deliverables, and an independent project-management department serves as an "honest broker" in resolving conflict or by representing the customer as tactical decisions are being made. For the GaAs business unit in AT&T Microelectronics, project management offers a business-like approach to the R&D challenges of the 1990s.

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